Evaluation of a Non-Contrast-Enhanced MR Angiography method in PVD patients and comparison with TRICKS

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Introduction

Several new non-contrast enhanced MR angiography (NCE-MRA) methods have recently been developed for imaging the arterial system without the time and resolution limitations of acquisition during first pass of a gadolinium-based contrast agent, or safety concerns related to Nephrogenic Systemic Fibrosis. VANESSA [1], a recently demonstrated NCE-MRA technique, is based on subtraction of bright- and dark-blood images obtained using a controllable flow suppression module. This approach has been used to achieve excellent visualisation of the peripheral arteries in healthy volunteers, and promising results in a preliminary investigation in patients [2]. The aim of this study was to assess the diagnostic performance of this method, in patients with peripheral vascular disease, by comparison with our standard clinical images obtained using a contrast enhanced method: 'time resolved imaging of contrast kinetics' (TRICKS) [3].

Materials/Methods

34 suspected arteriopaths (24 male, 10 female; mean age 66, range 42–81) referred for routine peripheral MR angiography, were examined using a 1.5 T Signa HDx scanner (GE Healthcare, Waukesha, WI). Ethical committee approval was obtained and all patients gave informed consent. The NCE-MRA sequence consisted of a 90° fat suppression pulse, followed by a modified MSDE flow-preparation module [1] and a 3D balanced SSFP readout. The flow-preparation was timed to peak arterial flow, determined from an initial cine phase-contrast acquisition.

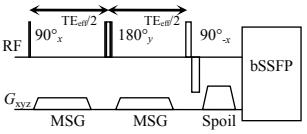

Fig. 1: modified MSDE module.

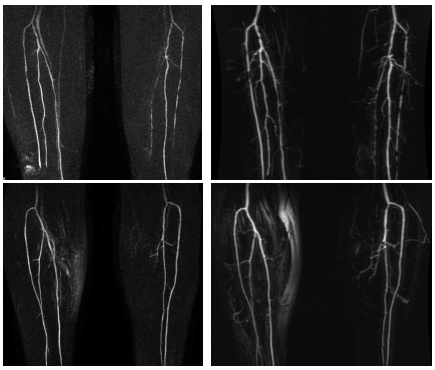

Fig. 2: Example comparisons in two patients of NCE (left) and TRICKS (right) MIPs.

The flow-preparation module (Fig. 1) consisted of 90°$_x$, composite 180°$_y$ and composite 90°$_{-x}$ pulses with an effective echo time (TE_{eff}) of 25 ms. The motion sensitisation gradients (MSG) had duration 8 ms. Four different flow sensitivities (MSG amplitudes 0.5, 1.0, 2.0, and 20.0 mT/m, corresponding to venc 22.4, 11.2, 5.6 and 0.56 cm/s) and a bright-blood image (acquired with no MSG) were acquired in a single acquisition. Subtraction of bright- and dark-blood images gave a set of vascular images, showing first fast and then slowly flowing vessels [1].

Scan parameters were as follows: TE/TR 1.8/3.8 ms; 1.0 Nex; flip angle 65°; acquired matrix 256×230×48; FoV 33.3×30 cm^2; coronal orientation; parallel imaging (ASSET, factor 2); acquired resolution 1.3×1.3×1.4 mm^3. The scan time is 48 heartbeats per phase, or 240 heartbeats in total (4 minutes at 60 bpm).

This was followed by our standard clinical protocol using TRICKS, with the following scan parameters: TE/TR 2.8/8.3 ms; flip angle 45°; FoV 44×30 cm^2; acquired matrix 512×156×28; acquired resolution 0.9×2.0×2.4 mm^3. The total scan time for a mask phase and 10 dynamic phases was 170 seconds. A dose of 10 ml Gadobutrol (Gadovist, Schering AG) was given, followed by a 20 ml saline flush, at a rate of 0.5 ml/second.

The images were cropped, giving the same S/I FoV for the two techniques, and assessed independently by two experienced radiologists. Both MIPs and individual slices were available for assessment. Eight arterial segments were assessed for each leg: below-knee popliteal (Pop), proximal and distal anterior tibial (AT), TP-trunk (TPT), proximal and distal peroneal (Per) and proximal and distal posterior tibial (PT). Firstly the visualisation of the segment was assessed, as fully, partially or not visualised. Any signal loss believed to be due to the imaging technique was noted. Arterial disease was then evaluated on a 4-point scale (0=normal; 1=stenosis<50%; 2=stenosis>50%; 3=occlusion). The presence of venous contamination and other artifacts were each scored on a 3-point scale (0=none; 1=not affecting diagnosis; 2=affecting diagnosis), and diagnostic confidence was scored on a 5-point Likert scale (0–4). From the disease evaluation, the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for detection of significant stenosis (>50%) were evaluated, considering TRICKS as the 'gold standard'. Segments rated as non-diagnostic (ND) were included in the analysis and counted as disagreeing between the methods. All statistical analysis was done using Microsoft Excel.

Results

Each reviewer evaluated 544 segments for each technique. Combining the results from both reviewers, 776/223/89 segments (NCE) and 991/45/52 segments (TRICKS) were graded as visible/partially visible/not visible. Technique-related signal loss was judged to have occurred for 194 segments (NCE) and 12 segments (TRICKS).

Reviewer	Method	0	1	2	3	ND	Total
Reviewer 1	NCE	382	61	38	52	11	544
	TRICKS	431	36	36	33	8	544
Reviewer 2	NCE	436	27	23	49	9	544
	TRICKS	467	18	19	35	5	544

Table 1: Number of segments given each disease score.

Table 1 shows the numbers of segments given each disease score. Table 2 compares numbers of segments assigned each score for the two methods, for both reviewers combined. There was agreement in 78.1% of segments, with NCE undercalling the TRICKS score in 5.1% and overcalling in 13.7% of cases. The Cohen kappa was 40.4% indicating moderate but not good agreement between the methods.

		TRICKS					
		0	**1**	**2**	**3**	**ND**	**Total**
NCE	**0**	770	22	8	8	10	818
	1	68	10	8	2		88
	2	21	10	21	8	1	61
	3	23	12	15	49	2	101
	ND	16		3	1		20
	Total	898	54	55	68	13	1088

Table 2: Comparison of scores between methods.

Table 3 shows the calculated sensitivity, specificity, PPV and NPV calculated on a per-segment, per-limb and per-patient basis, and additionally the per patient result when patients in whom one or more segments were judged non-diagnostic (confidence = 0) were removed from this analysis.

Combining results from both reviewers, venous contamination was scored as 0/1/2 for 840/197/51 segments (NCE) and 532/5/7 segments (TRICKS). Other artifacts were scored as 0/1/2 for 984/96/8 segments (NCE) and 886/186/16 segments (TRICKS).

For the diagnostic confidence assessment, 40/51/82/192/723 segments (NCE) and 15/8/6/32/1027 segments (TRICKS) were assigned scores of 0/1/2/3/4 respectively. The mean±sd diagnostic confidence was 3.4±1.1 for NCE and 3.9±0.6 for TRICKS.

Method	Sensitivity	Specificity	PPV	NPV
Per segment	75.6% (93/123)	91.4% (870/952)	57.4% (93/162)	96.0% (870/906)
Per limb	89.7% (56/77)	72.7% (52/58)	70.3% (52/74)	90.3% (56/62)
Per patient	97.6% (40/41)	44.4% (12/27)	72.7% (40/55)	92.3% (12/13)
Per patient excl confidence 0	100.0% (26/26)	50.0% (9/18)	74.3% (26/35)	100.0% (9/9)

Table 3: Calculated sensitivity and specificity for evaluation of significant disease (stenosis > 50%).

Discussion & Conclusions

This work demonstrates that a novel subtraction-based NCE-MRA method has a comparable performance to a conventional CE-MRA method in patients with peripheral vascular disease. The NCE sequence used for this study uses a bSSFP readout which can result in signal loss in patients, particularly in regions of poor shim such as around the edges of the field of view, and resulting partly from inflow effects. This may account for the NCE sequence overcalling disease relative to TRICKS. However, the high per-patient sensitivity and NPV suggest that this method could have value in selecting patients for further investigation by contrast-enhanced methods, reducing the administration of Gd to patients likely to have poor renal function. NCE and CE methods may also be complementary as the vascular signal characteristics have different sources, for example segments with very low flow will still eventually show contrast agent uptake but may not be detected on the flow-dependent NCE sequence. The NCE sequence may also suffer signal loss in the slow-flowing region downstream of a stenosis or occlusion. It is possible that the flow-dependent method could have value in assessing functional changes related to restricted flow.

For a final analysis of this data, a consensus review is planned for segments where the two reviewers were not in agreement. Several methodological improvements to the NCE sequence have been investigated since the beginning of this study, and further investigations will assess what impact these might have in patient studies.

References [1] Priest AN et al. Magn Reson Med (in press). [2] Priest AN et al. Proc ISMRM 2010; 18: 406.
[3] Turski PA et al. Top Magn Reson Imaging 2001;12:175–181.

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